Presentation to JPL Advisory Council

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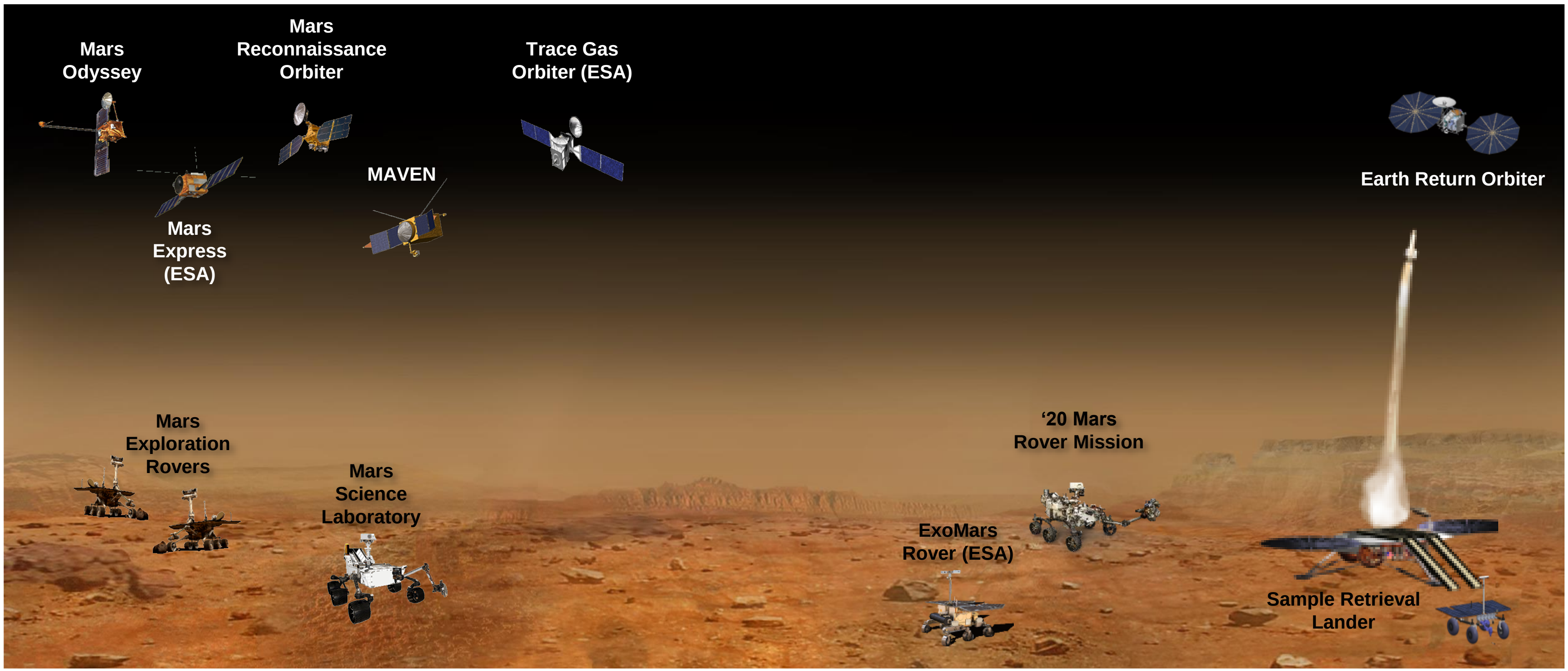
Director for Mars Exploration
October 29, 2018

Jet Propulsion Laboratory
California Institute of Technology

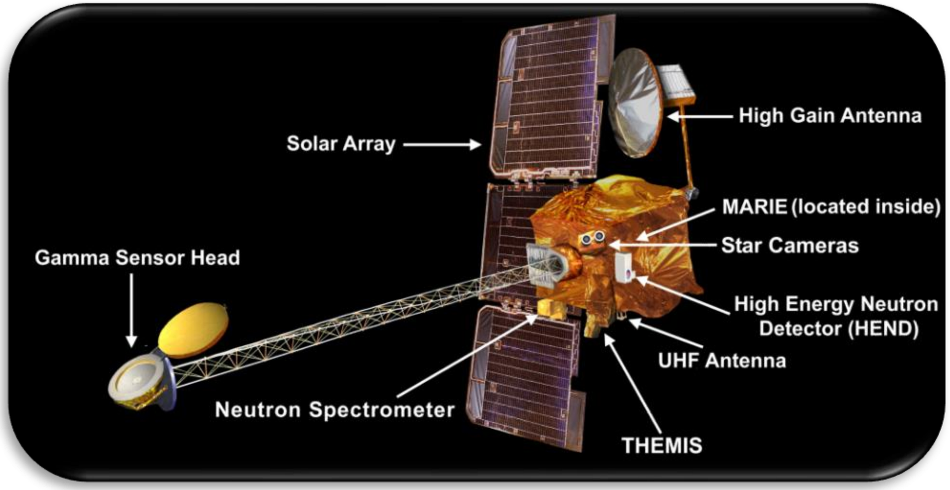
Mars Exploration Program Missions

2001 - 2015 | 2016 | 2018 | 2020 | Notional Future Mars Missions

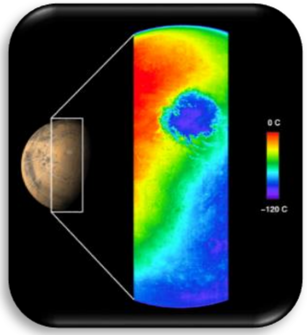


Pre-Decisional Information –
For Planning and Discussion Purposes Only

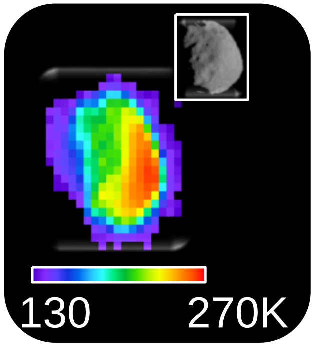
Mars Odyssey



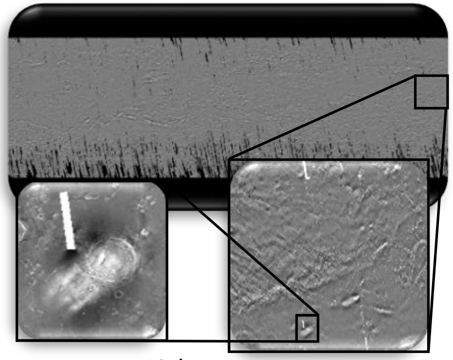
- Launched 4/7/01, MOI: 10/24/01
- Odyssey is in good health: anticipating to support relay of landed systems with extended mission science objectives ahead
  - Longest serving spacecraft at Mars; longest surviving spacecraft in orbit around another planet besides Earth
  - ~ 75,000 orbits since MOI
  - ~ 11.9 years of fuel remaining [however, other subsystems might limit life]
  - S/C in 645 AM/645 PM orbit
- Skew reaction wheel in use since June 2012
- Plan for All Stellar mode in January 2019, preserves IMU life



Temperature South Pole



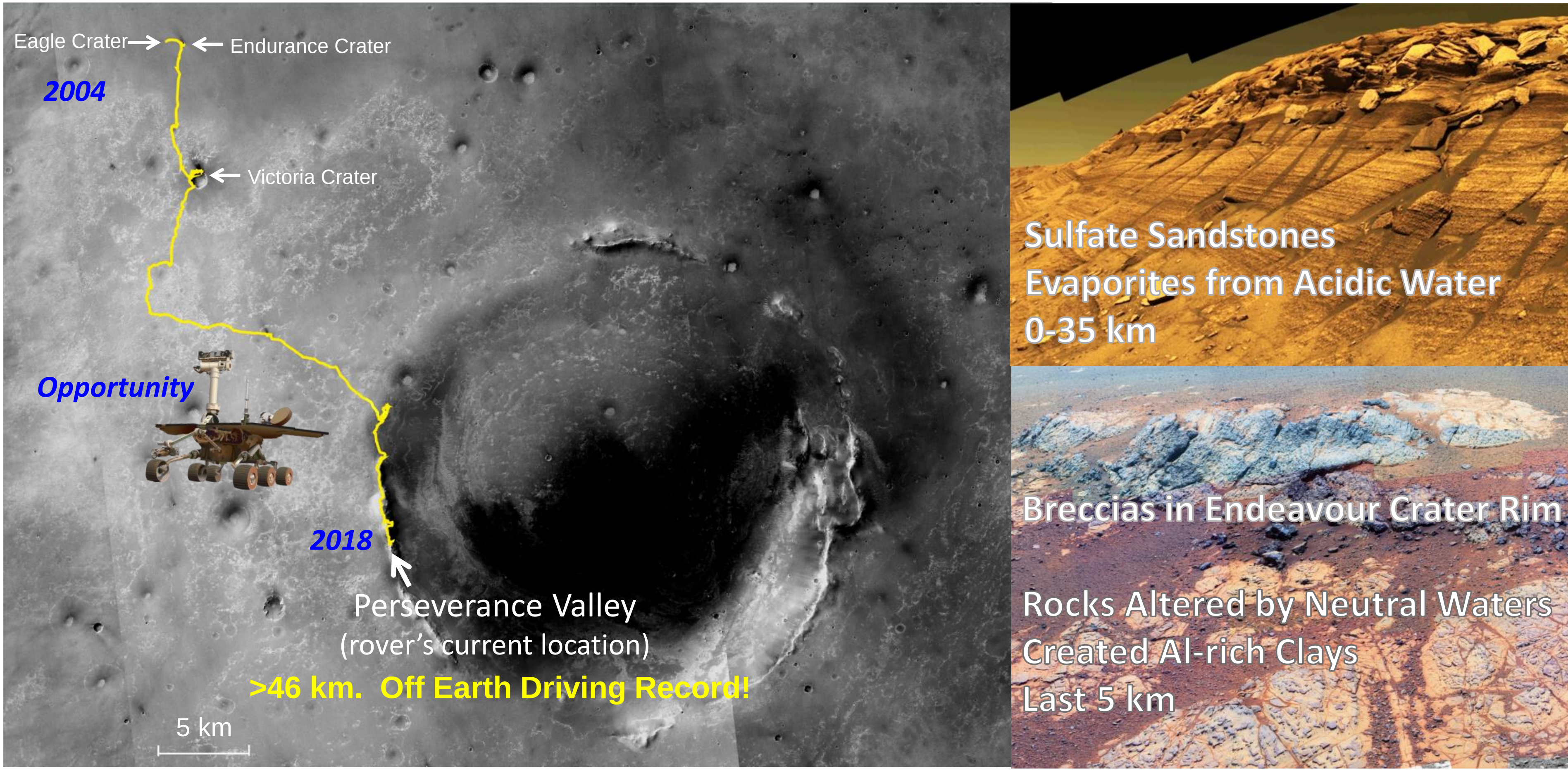
Phobos Thermal Map



Night IR Map

- Key THEMIS observations:
  - Global IR day and night maps
  - Continuous record of atmospheric and surface activity for 8 Mars years
  - First Phobos and Deimos IR image
  - Discovered chloride salts in southern highlands

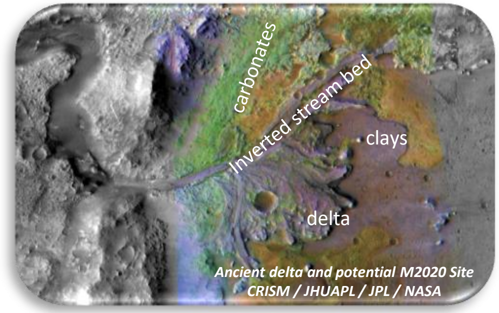
Opportunity: Ancient Aqueous Environments on Mars



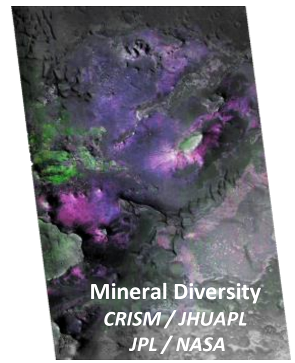
- Planet-encircling dust event started in June'18: have not been able to communicate with Opportunity since ~ Jun 11 – the atmospheric opacity was very high and rover very likely went into low power fault mode, including loss of master clock
- Have been listening for signal using "Beep-and-sweep" approach since Sep 11 when opacity had subsided to a level with enough solar power for rover to wake up
    - No signal had been received
    - Active listening on-going

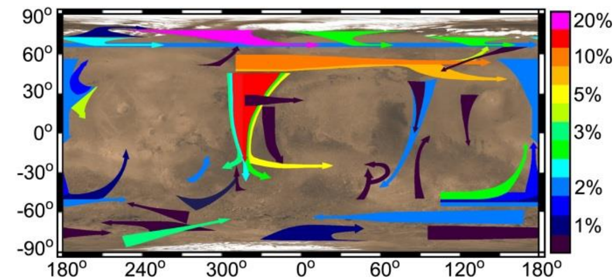
Mars Reconnaissance Orbiter

Recurring Slope Lineae



Identification of many aqueous environments
Jezero Crater (Mars 2020 Candidate Landing Site)





Climatology of Martian regional dust storm tracks as percent of total number for MY23-32 (Cantor, 2016)

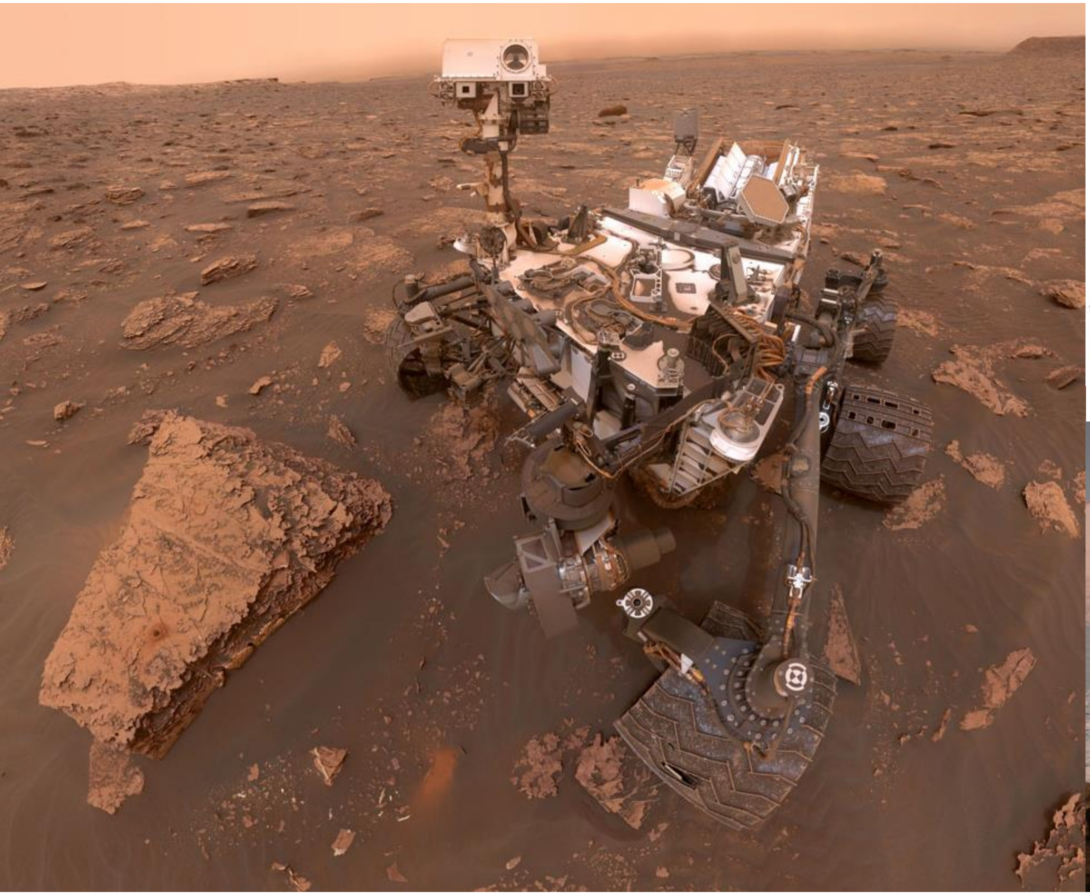
Technical Status:

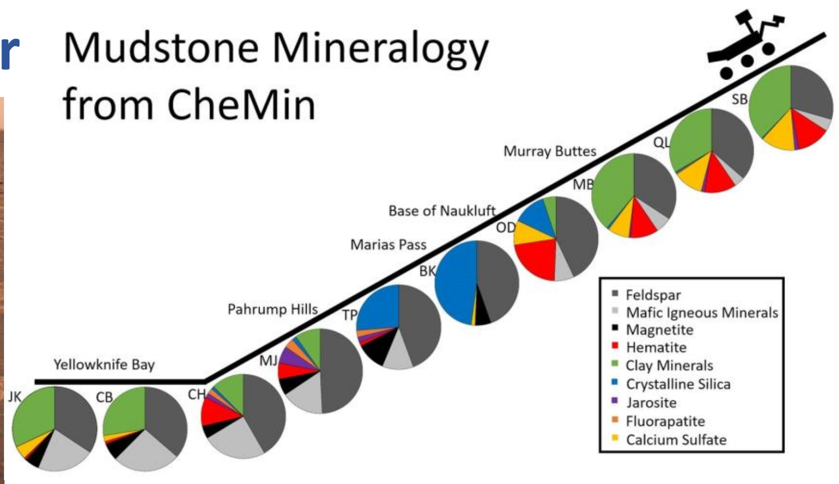
- Extended mission operation has both scientific and programmatic (relay, reconnaissance, critical event coverage) objectives
- Spacecraft is healthy – large fuel reserves (~200 kg; >20 years)
- Working to extend spacecraft lifetime:
  - Developed all-stellar attitude determination capability to preserve IMU life
  - Implemented power load management to extend battery life with reconditioning of spacecraft batteries
- Recent UHF telecom relay experienced intermittent low performing relay passes => active anomaly investigation
  - Preparations for *InSight EDL* critical event coverage and UHF surface relay support

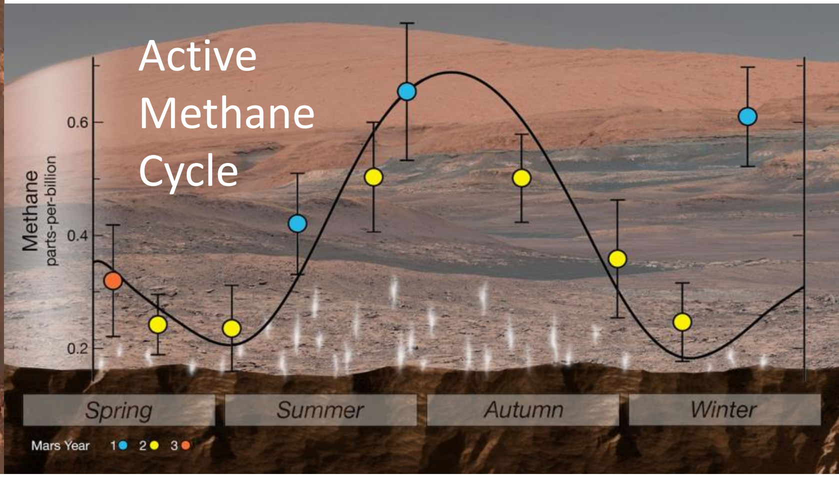
Science Status:

- Established the presence of many different aqueous environments in the Martian past
- Detected thick (>100 m) ice deposits revealed in mid-latitude ice cliffs preserved beneath thin (<20 m) debris blankets
- Quantified global variation of air temperatures, ice and dust aerosols with time, extending Mars climatology record to 10 Mars years
- Revealed a dynamic planet: Recurring Slope Lineae (RSL), moving sand dunes, erosion by subliming CO_2 ice, quasi-regular seasonal dust storms with two planet-encircling dust events and over a thousand new impact craters observed in the last 6 Mars years

Mars Science Laboratory/Curiosity Rover

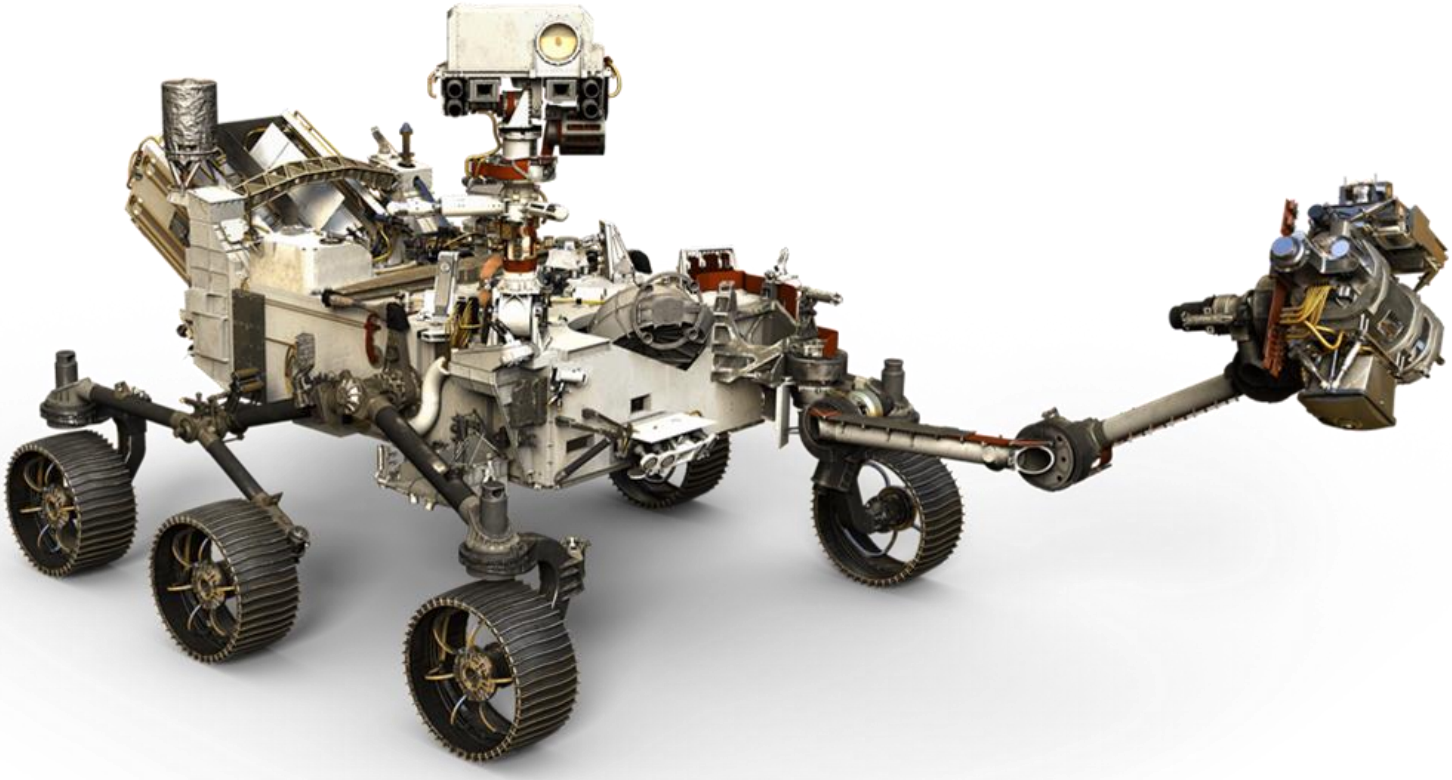






- Curiosity has been exploring Aeolis Mons (Mount Sharp) in Gale crater for over six years, traversing 20 km, climbing over 300 m in elevation, analyzing 17 drilled samples, and collecting three Mars years of meteorology and radiation measurements.
- The mission has discovered that a series of lakes and groundwater systems created habitable conditions. Rocks in Gale crater contain a diversity of organic molecules that have been preserved over billions of years. Detected an active Methane annual cycle.
- Resolved drill feed mechanism failure by successfully implementing “Feed Extended Drilling” to drill directly with arm
- Encountered issue with data product catalog on B-side computer [data storage] on 9/16/18. Swapped to A-side to facilitate diagnosis. Expect full recovery.

Mars 2020 status



Mission Overview

LAUNCH

- Atlas V 541 vehicle
- Launch Readiness Date: July 2020
- Launch window: July/August 2020

CRUISE/APPROACH

- ~7 month cruise
- Arrive Feb 2021

ENTRY, DESCENT & LANDING

- MSL EDL system (+ Range Trigger and Terrain Relative Navigation): guided entry and powered descent / Sky Crane
- Access to landing sites ±30° latitude, ≤ -0.5 km elevation

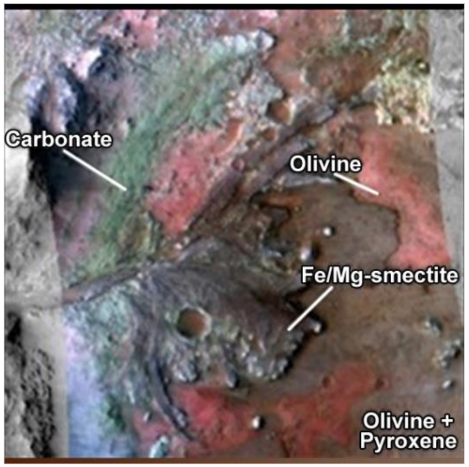
SURFACE MISSION

- 20 km traverse distance capability
- Enhanced surface productivity
- Qualified to 1.5 Martian year lifetime
- Seeking signs of past life
- Returnable cache of samples
- Prepare for human exploration of Mars

627 days to launch period [Jul 17’20]

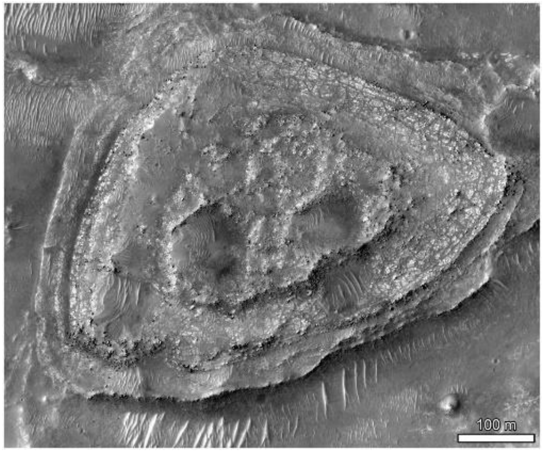
843 days to landing [Feb 18’21]

Mars 2020 Candidate Landing Sites



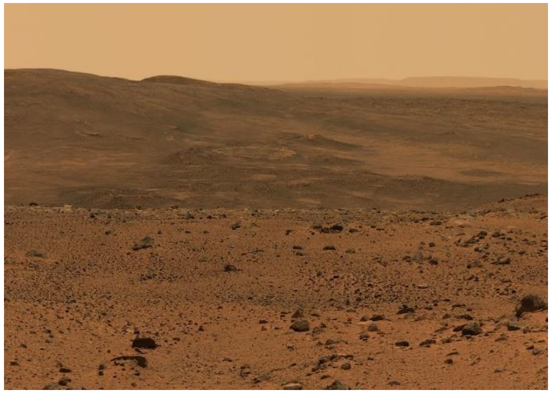
JEZERO

- Minerologic diversity including clays and carbonates
- Shallow water carbonates?



NE SYRTIS

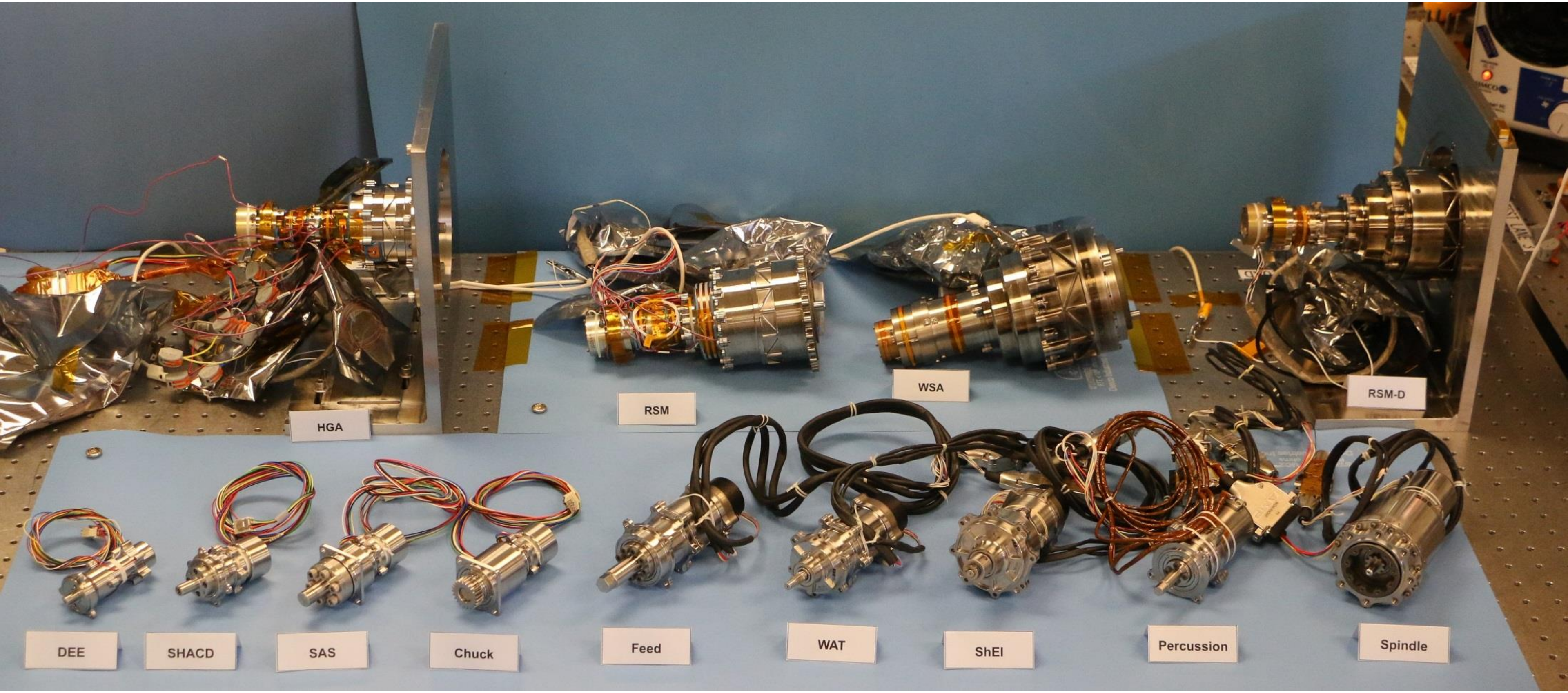
- Extremely ancient igneous, hydrothermal, and sedimentary environments
- High mineralogic diversity with phyllosilicates, sulfates, carbonates, olivine



COLUMBIA HILLS

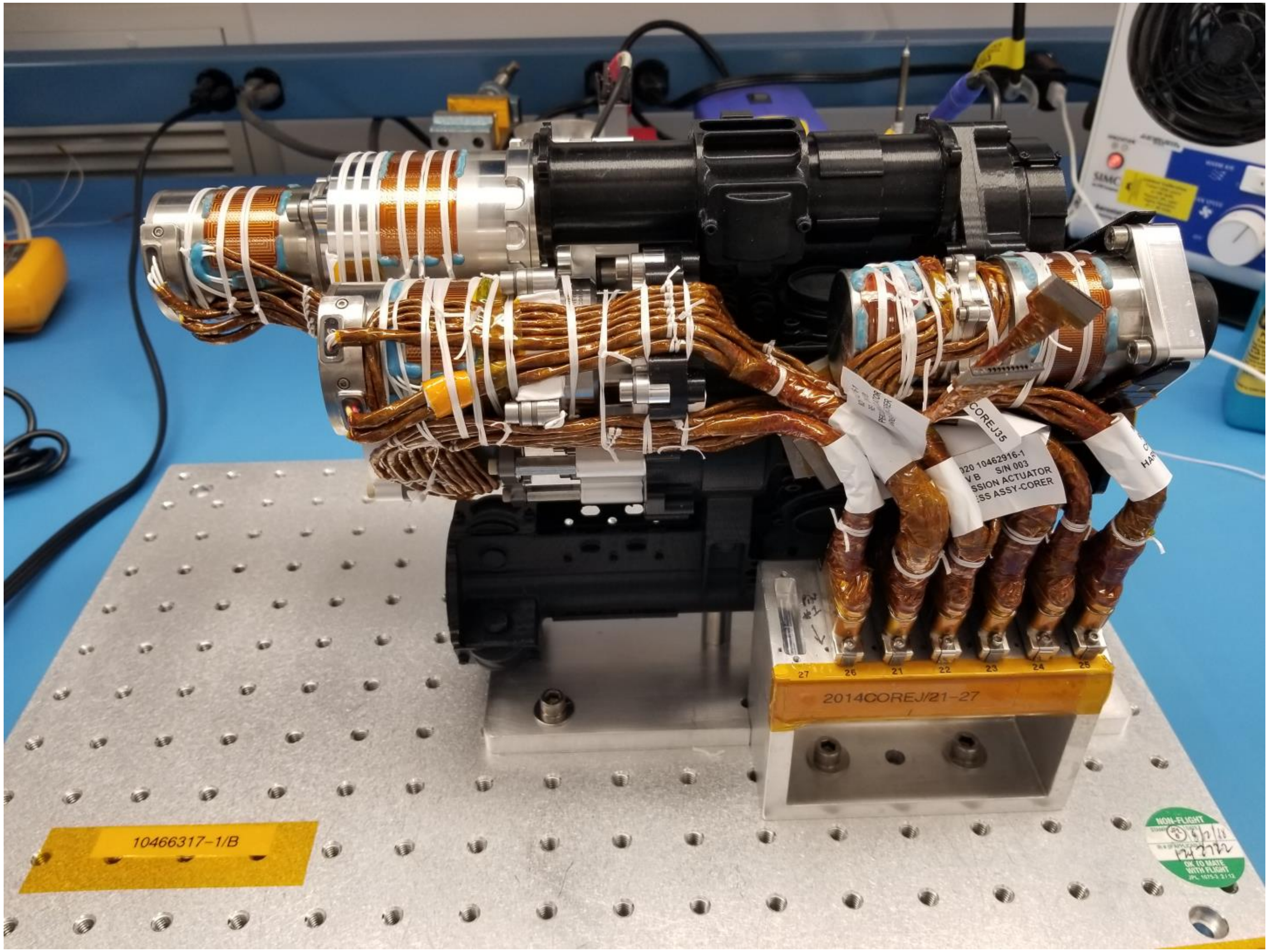
- Carbonate, sulfate, and silica-rich outcrops of possible hydrothermal origin. Hesperian volcanics.
- Previously explored by MER

Flight Actuators

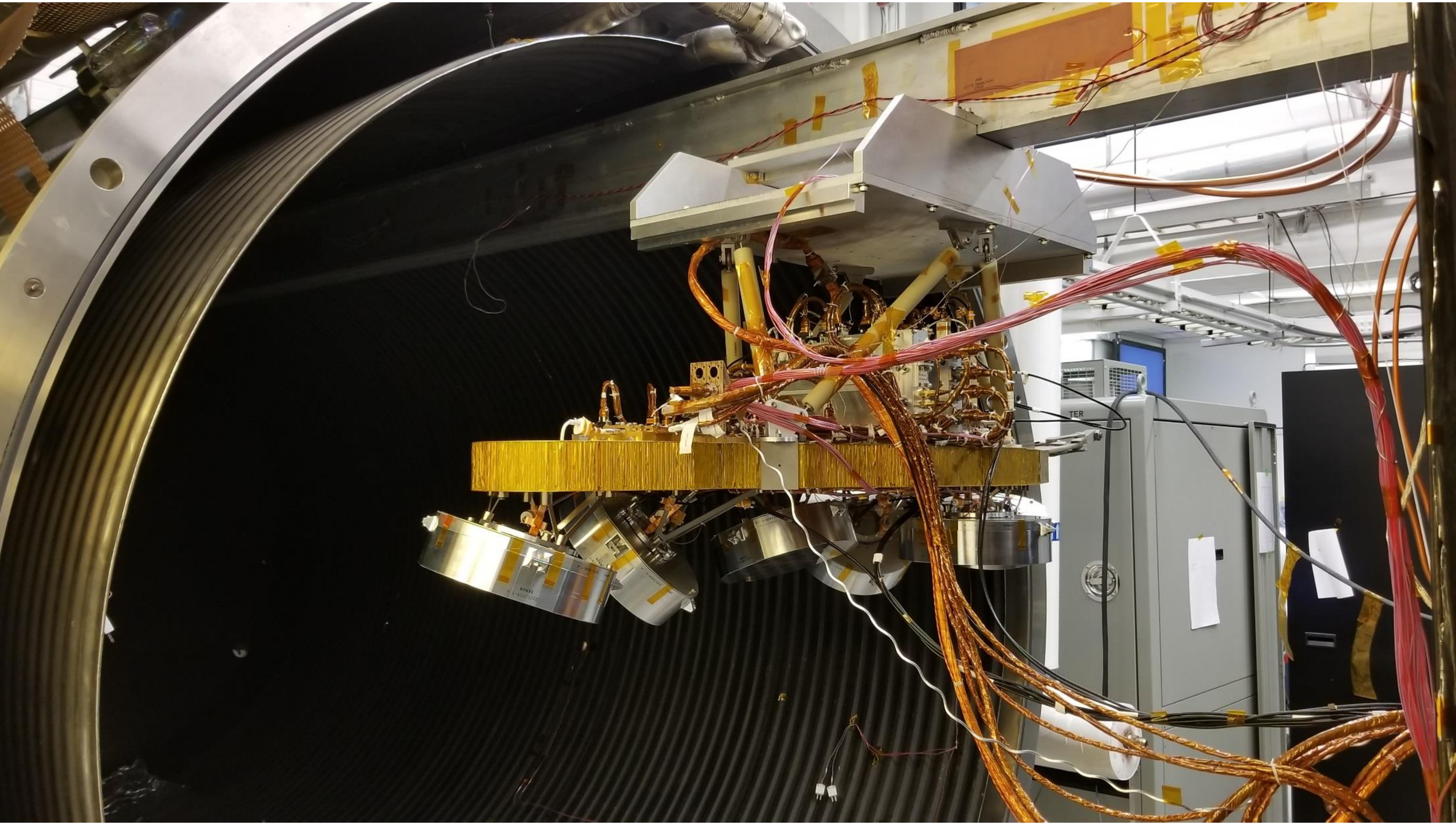


Sampling System: EM Robotic Arm

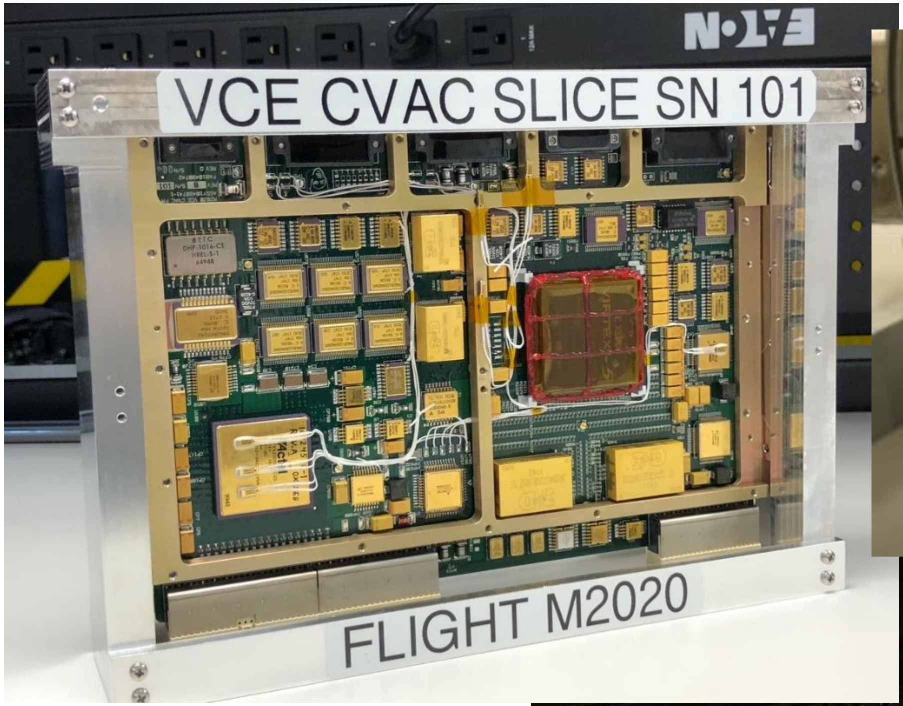
Sampling System: Flight Corer



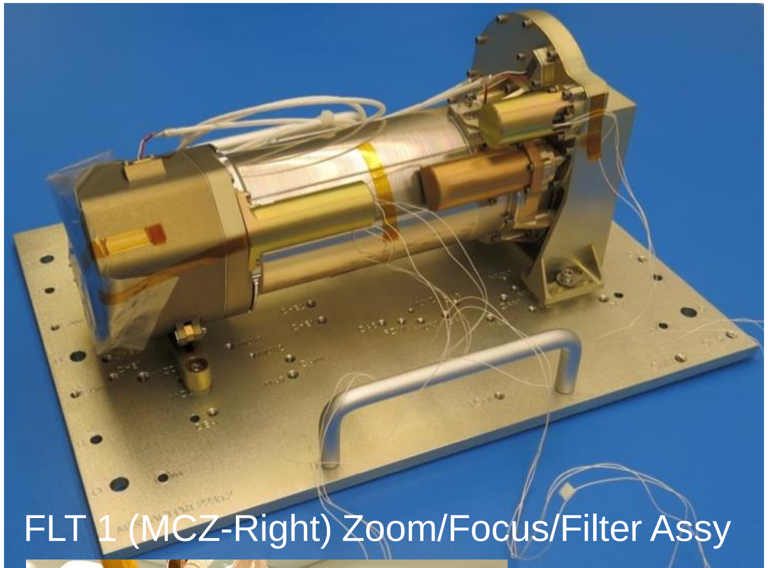
Landing Radar



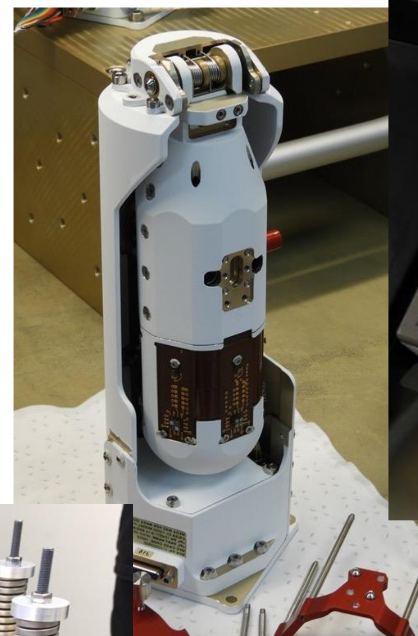
Terrain Relative Navigation / Fast Traverse

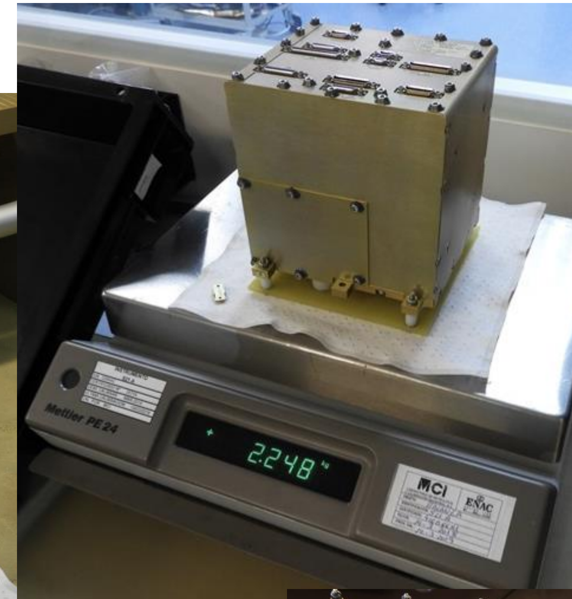


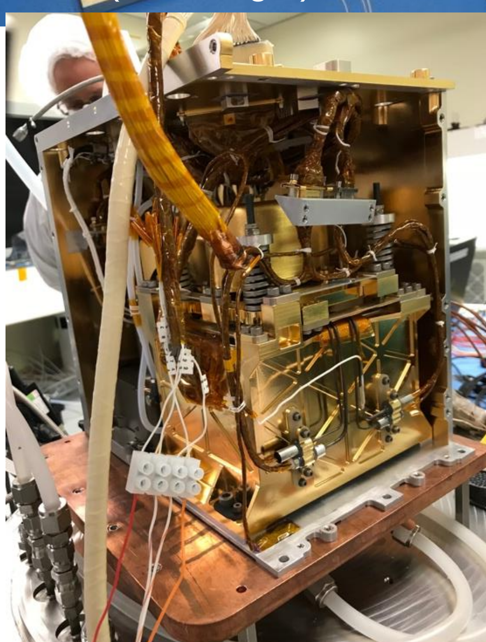
Mastcam-Z, MEDA, MOXIE, RIMFAX Pictures

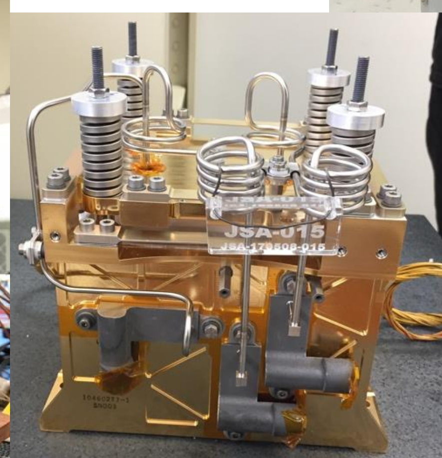

FLT 1 (MCZ-Right) Zoom/Focus/Filter Assy

MEDA PFM ICU
& Wind Sensor 2 FM

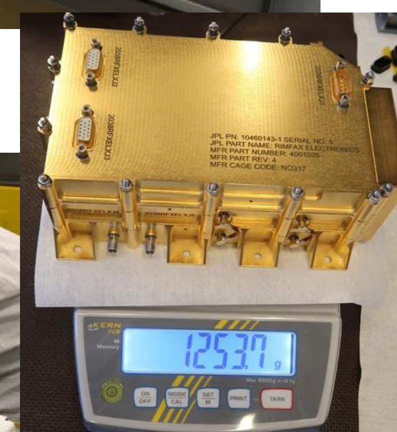






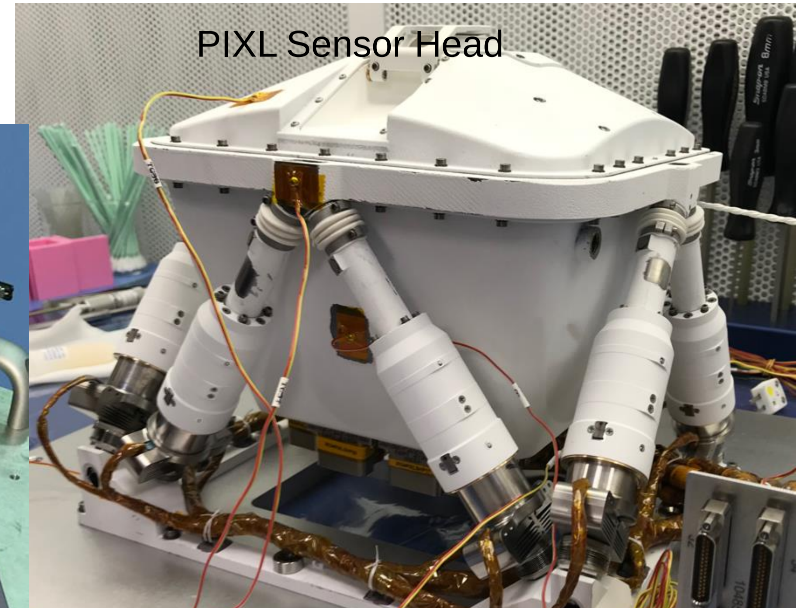


MOXIE EM SOXE and
EM assembly (left)

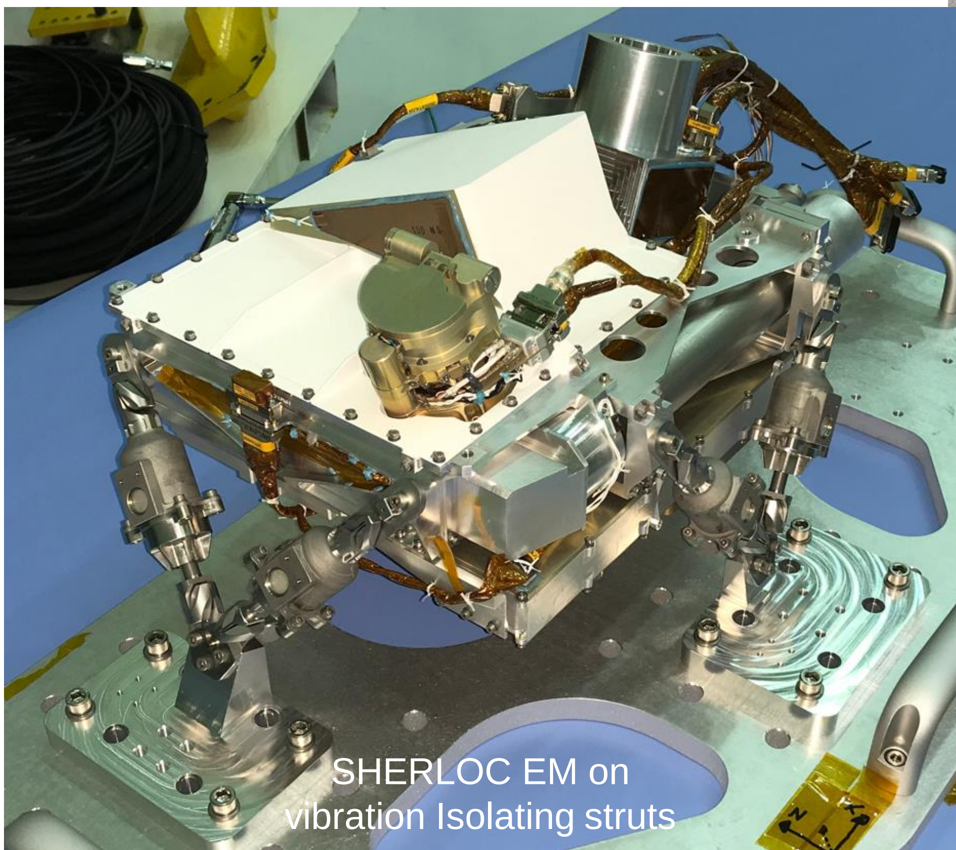


RIMFAX FM
electronics &
antenna

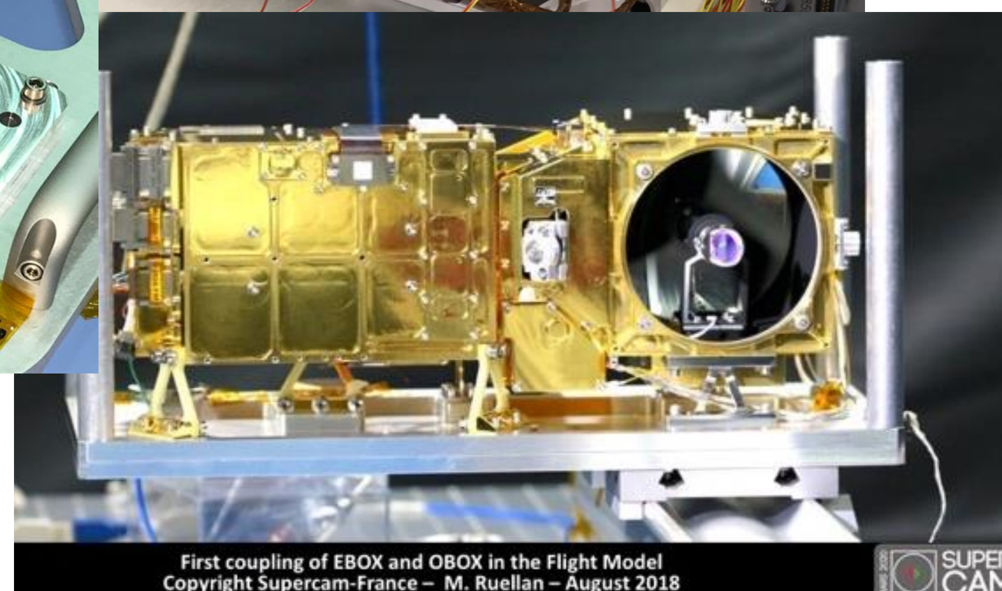
PIXL, SHERLOC, SuperCam Pictures



PIXL Sensor Head



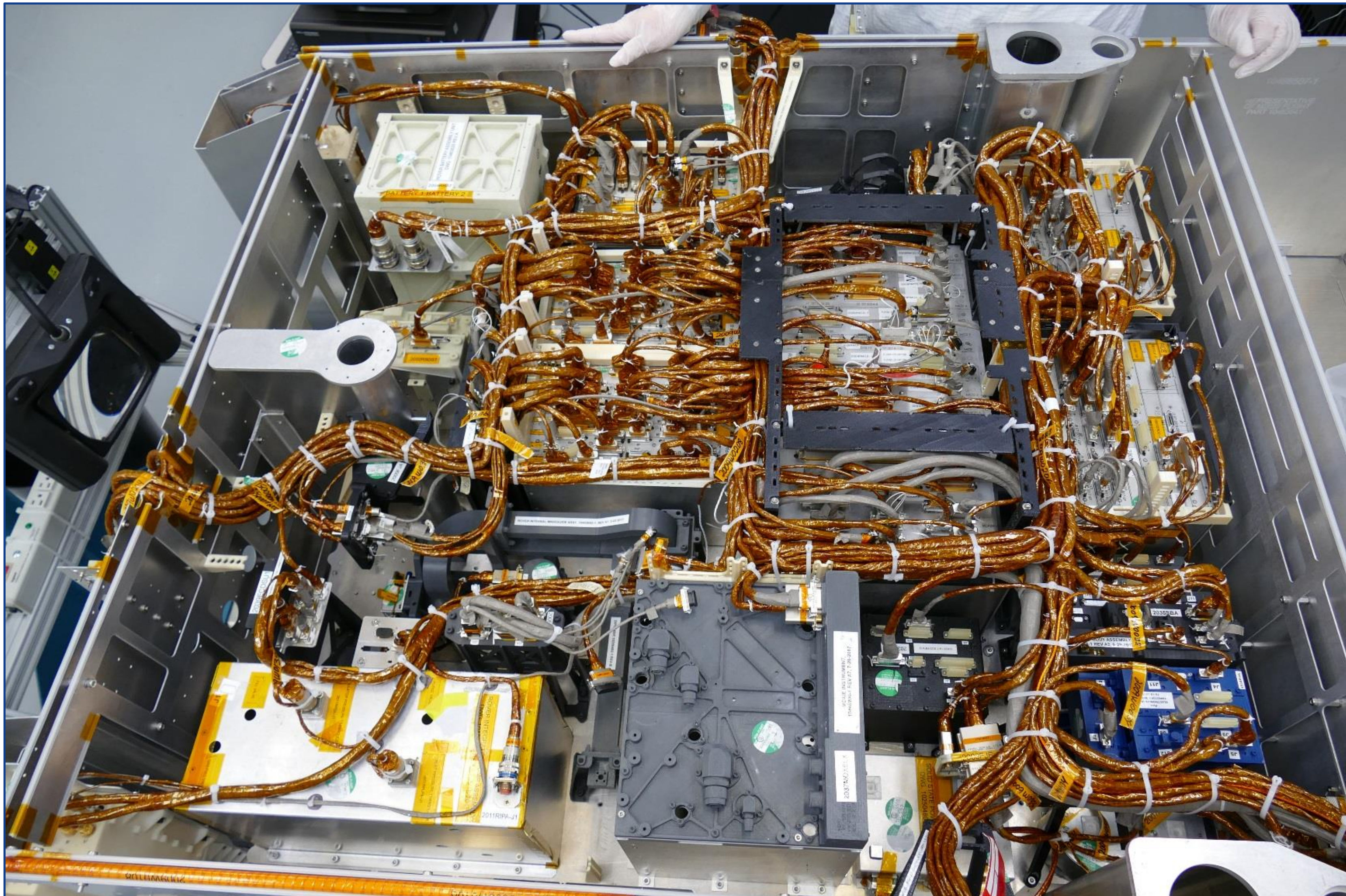
SHERLOC EM on vibration Isolating struts



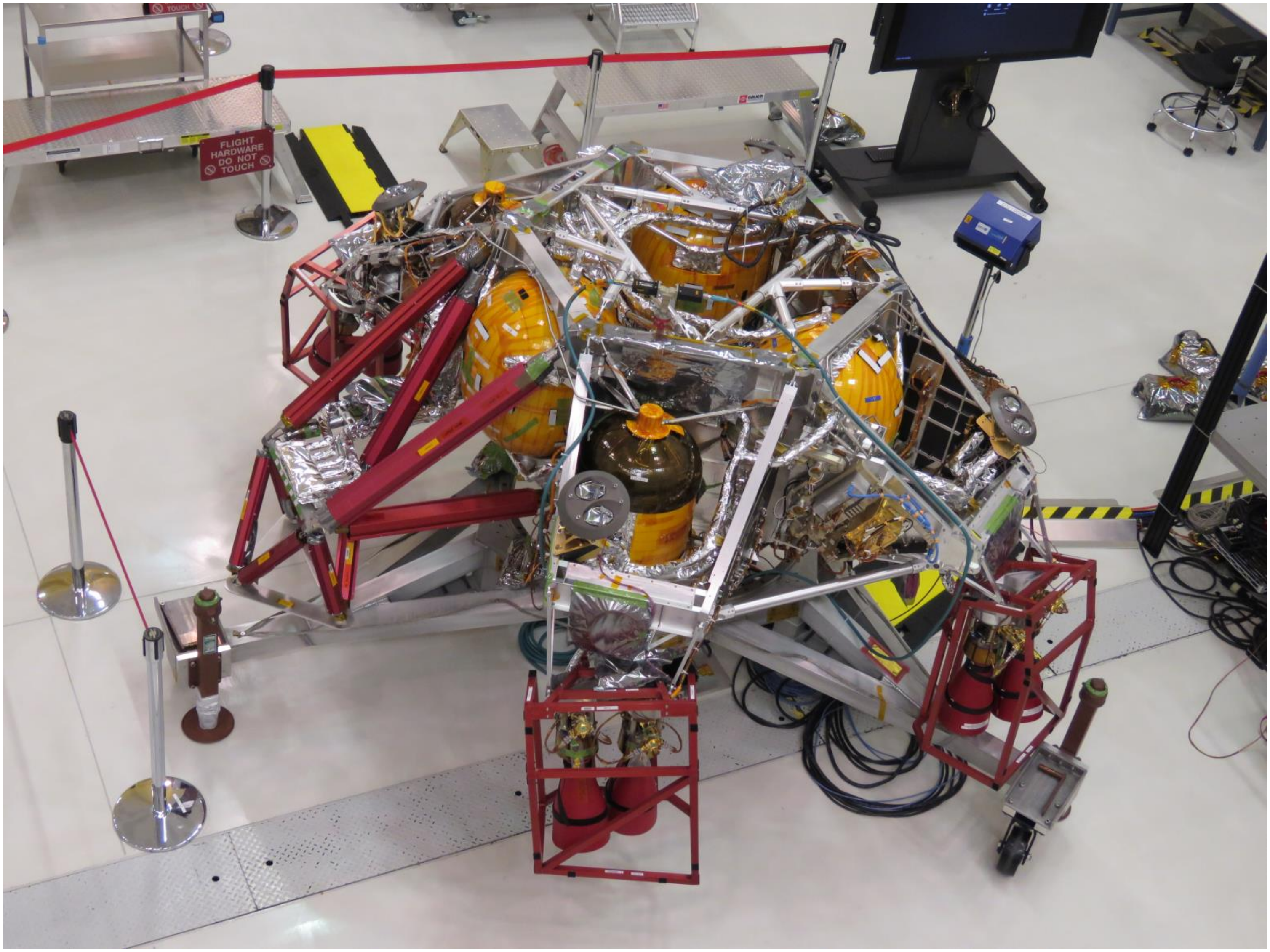
First coupling of EBOX and OBOX in the Flight Model
Copyright Supercam-France – M. Ruellan – August 2018

Rover Chassis Integration in ATLO

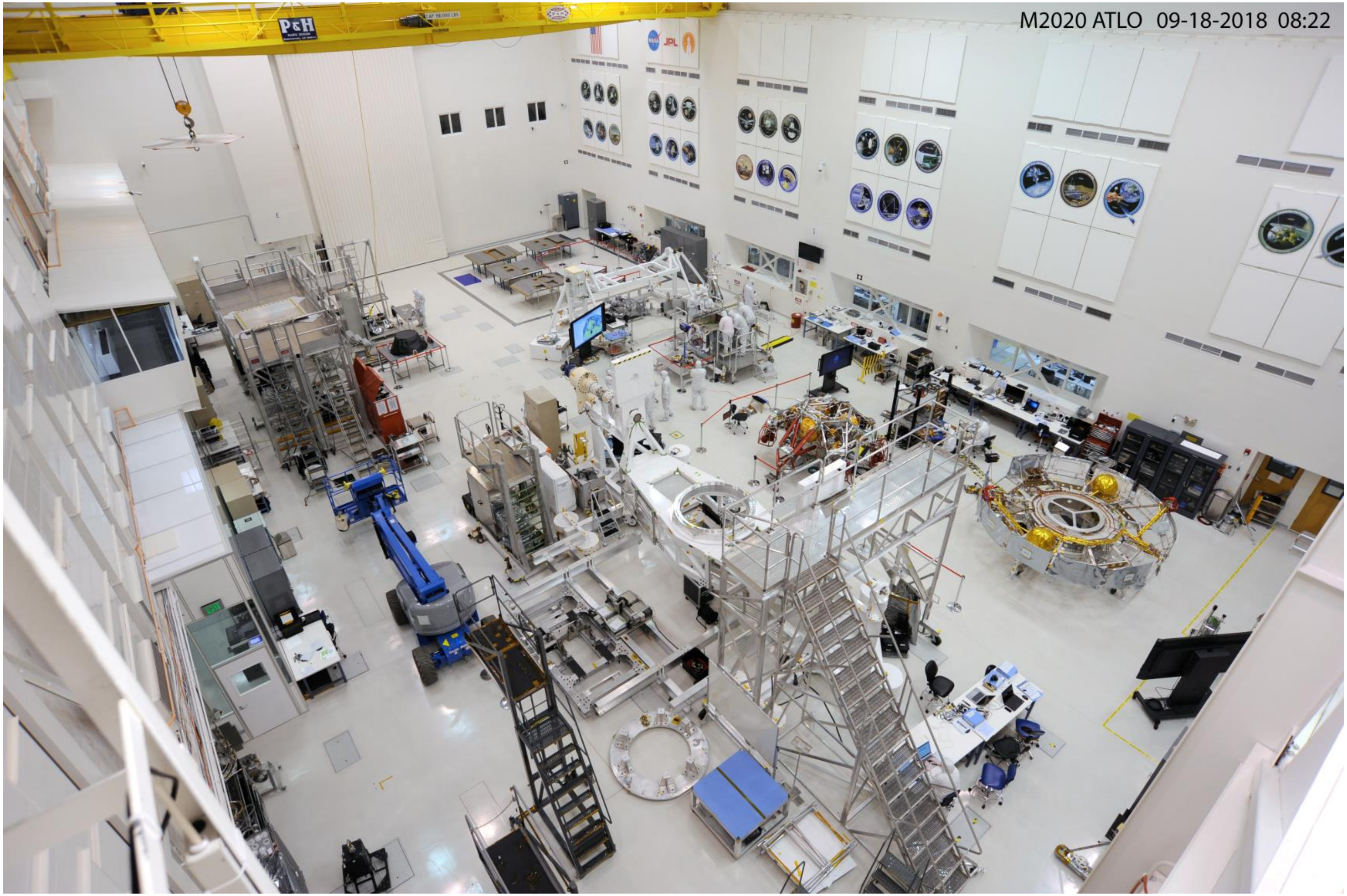
Internal Chassis Integration



Flight Descent Stage

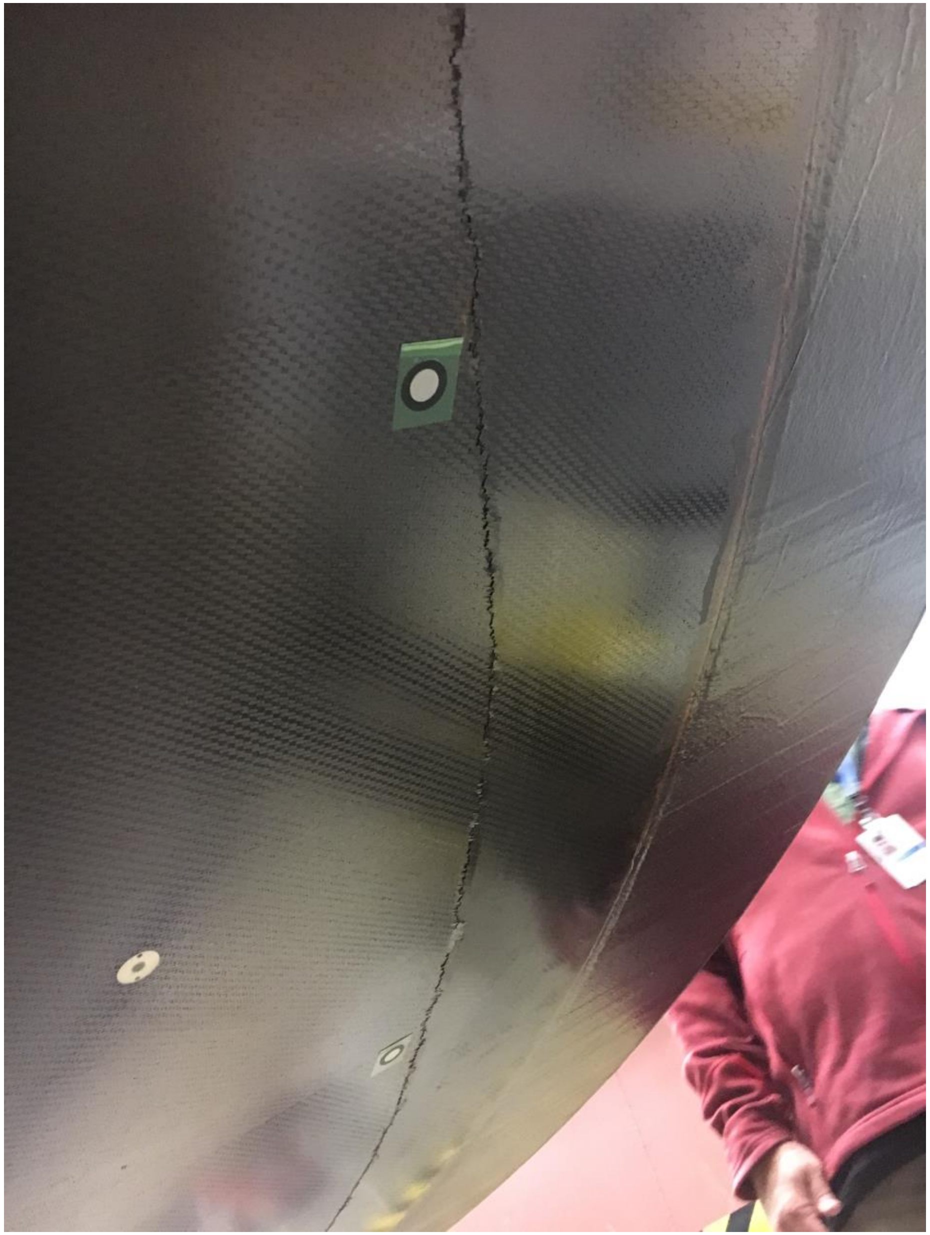


ATLO Floor



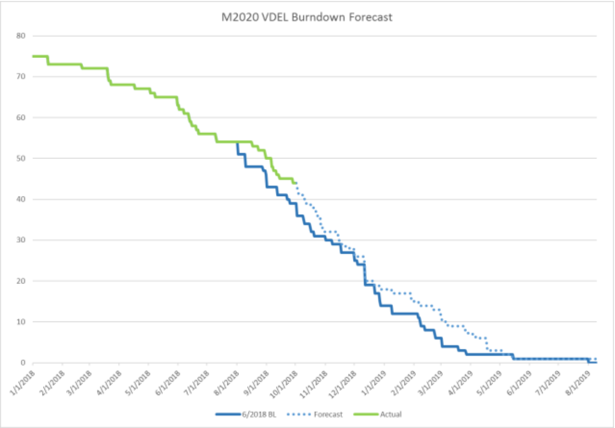
Final Parachute Supersonic Test

Heat shield test problem



Mars 2020 Key Steps

- Maintain pace of subsystem delivery in next 6 month
  - Subsystem delivery schedule
    - Dec 1’18: ~50/75 planned to be complete
    - Mar 1’19: ~65/75 planned to be complete
  - Special focus on key critical path items
    - Sampling system delivered in Jan-Apr’19
    - SHERLOC/PIXL: April’19



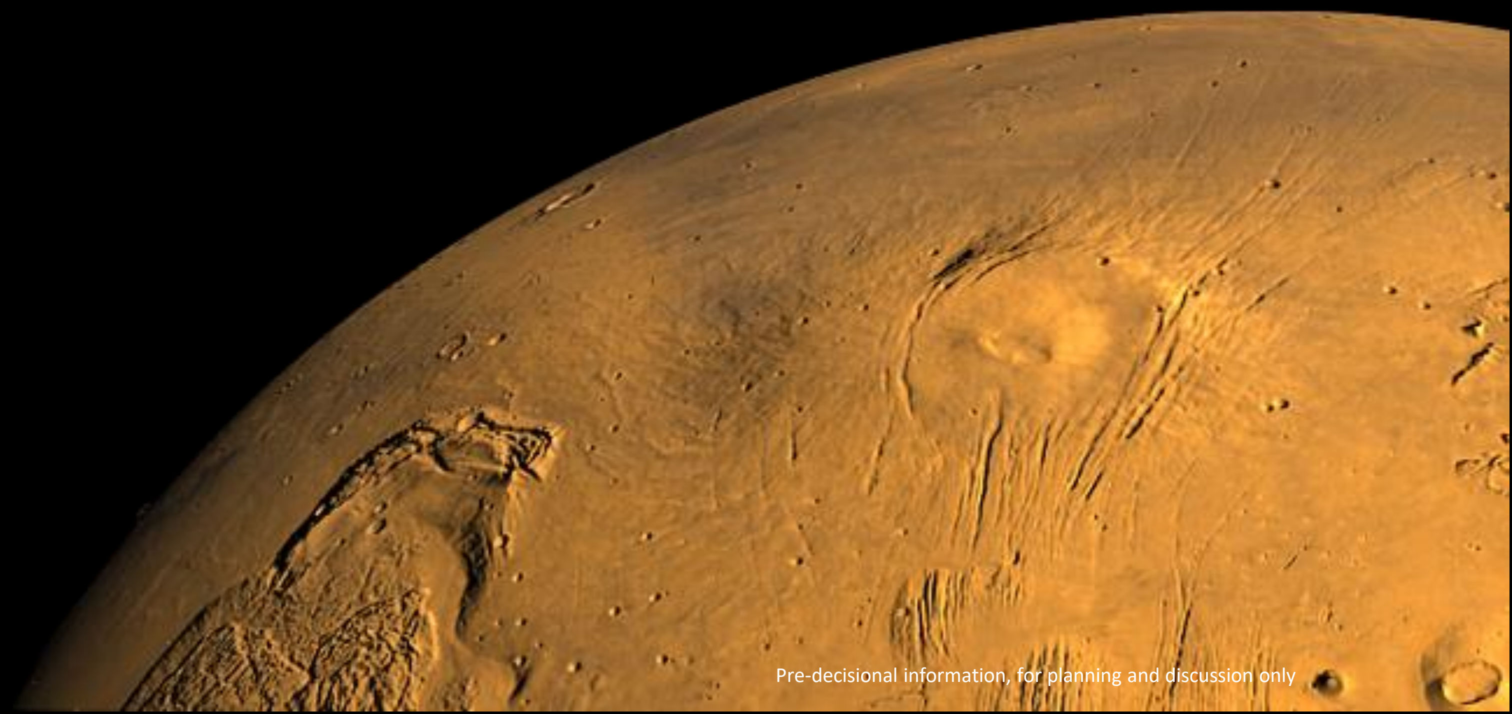
- Landing site selection

- Complete V&V at Level 4 and higher

- Be vigilant on paper work burn-down: PFRs; etc

- Complete current cost-to-go assessments and interactions with HQ

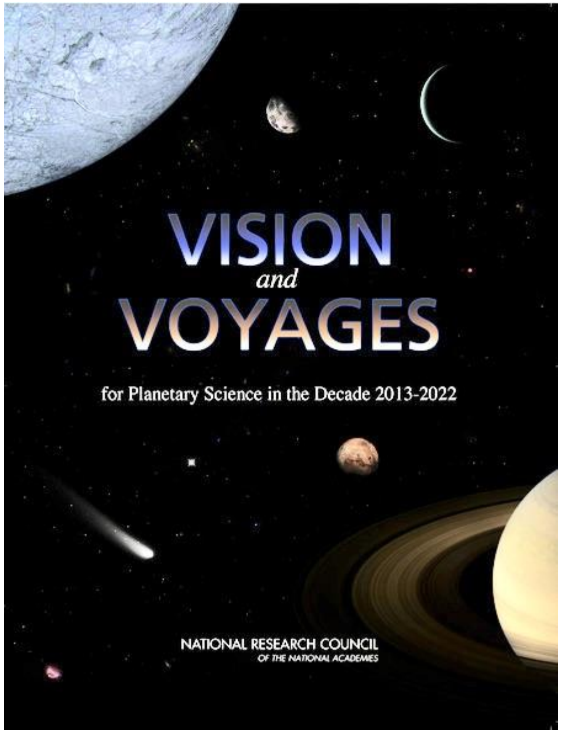
Mars Sample Return Architecture Studies



Pre-decisional information, for planning and discussion only

Mars Sample Return – a Decadal Survey Priority

- ***The NRC Planetary Science Decadal Survey (2011) provided a strong recommendation for MSR***
  - “**The major focus of the next decade will be to initiate a Mars sample-return campaign**, beginning with a rover mission to collect and cache samples, followed by missions to retrieve these samples and return them to Earth.”
  - “**A critical next step …. will be provided through the analysis of carefully selected samples** from geologically diverse and well-characterized sites that are returned to Earth for detailed study using a wide diversity of laboratory techniques”
  - “**The highest priority Flagship mission for the decade of 2013-2022 is MAX-C** (Mars astrobiology explorer-cacher)"
  - “During the decade of 2013-2022, **NASA should establish an aggressive, focused technology development and validation initiative** to provide the capabilities required to complete the challenging MSR campaign.”

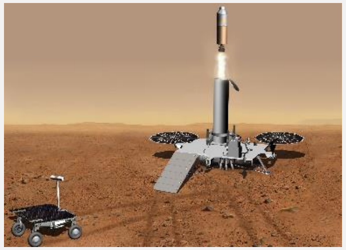


Notional Mars Sample Return Architecture

- Three flight elements plus one ground element
  - Limits the cost, mass/volume, and technical challenges of each flight element

Sample Caching Rover (Mars 2020)

- *Sample acquisition and caching*

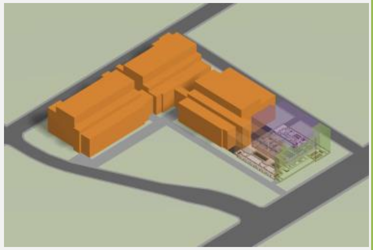


Sample Retrieval Lander*

- *Fetch Rover*
- *Orbiting Sample container (OS)*
- *Mars Ascent Vehicle*

Earth Return Orbiter*

- *Rendezvous and On-Orbit Capture System*
- *Earth Entry Vehicle*



Mars Returned Sample Handling*

- *Sample Receiving Facility*
- *Curation*
- *Sample science investigations*

Flight Elements | ***Ground Element***

*Concepts

NASA-ESA Joint Statement of Intent

- On April 26, 2018, in conjunction with the 2nd International MSR Conference in Berlin, GER, NASA and ESA signed a Joint Statement of Intent on Mars Sample Return
- NASA:
  - Lead MSR Campaign system architecture
  - Lead Sample Retrieval Lander mission
  - Provide Sample Capture, Handling, and Containment System and Earth Entry Vehicle to ERO
- ESA:
  - Lead Earth Return Orbiter mission
  - Provide Sample Fetch Rover and Sample Transfer Arm to SRL
- Joint plan to be developed for NASA/ESA approval by the end of CY 2019

Joint Statement of Intent between the National Aeronautics and Space Administration and the European Space Agency on Mars Sample Return

April 26, 2018

Pursuant to the highest objectives established by the international scientific community for planetary science, the National Aeronautics and Space Administration (NASA), and the European Space Agency (ESA), expressed a mutual interest in pursuing cooperation on Mars sample return activities through the signature of a 2008 Agreement addressing potential cooperation on future space exploration sample return activities that extends through December 31, 2020;

Recognizing that NASA and ESA continue sharing the common objective of together preparing and launching a set of complementary missions by the end of the next decade that would return samples from Mars to Earth for scientific research;

Recognizing that both agencies are implementing missions and conducting preparatory activities which will contribute to the realisation of a Martian sample return mission, including the NASA Mars 2020 mission that will cache samples for return to Earth and the ESA-Roscosmos Trace Gas Orbiter and ExoMars missions that will expand ESA's operational experience at Mars;

Recognizing that the 2016 ESA Council meeting at the Ministerial level mandated that ESA prepare for the next ESA Mars mission, considering European participation in an international Mars Sample Return (MSR) mission as a key objective;

Recognizing that the United States Fiscal Year 2019 President's Budget Request directs NASA to plan a potential MSR mission leveraging international and commercial partnerships; and

Recognizing NASA and ESA's mutual objective to collaborate on a joint MSR endeavor potentially based on a reference architecture under consideration whereby NASA would lead a MSR campaign as the systems architect and lead an MSR Lander (SRL) mission, and ESA would lead a MSR Orbiter mission and provide the Sample Fetch Rover and the Sample Transfer Arm to the SRL mission and NASA would provide the Sample Capture, Handling, and Containment system and the Earth Entry Vehicle to the MSR Orbiter; this endeavor may be in concert with other international or commercial partners;

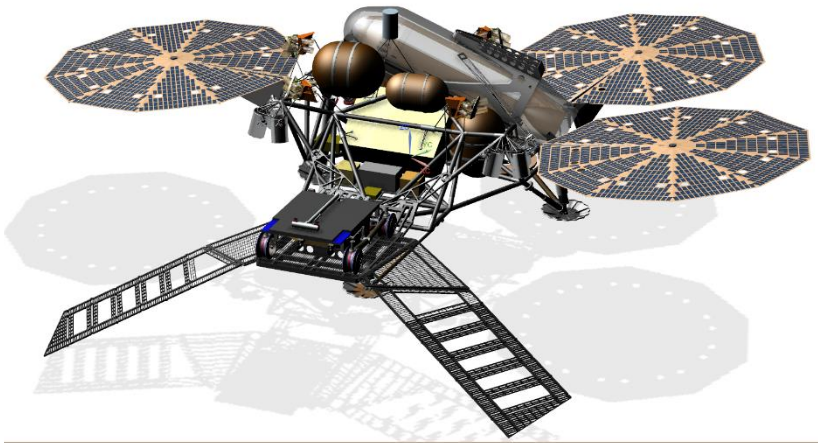
NASA and ESA intend to develop a joint MSR plan and to complete the studies needed to reach the level of technical and programmatic maturity required to pursue an effective MSR partnership, specifically defining the respective roles and responsibilities sufficient to lead to an international agreement between the two agencies in time to be submitted for approval to their respective authorities at the end of 2019.

Thomas Zurbuchen **Associate Administrator** **for Science** **NASA**	**David Parker** **Director** **Human and Robotic Exploration** **Programmes** **ESA**

Notional Sample Retrieval Lander

- Key Functions:
  - Deliver Fetch Rover and MAV to appropriate landing site to achieve sample tube pick up and transfer to the Orbiting Sample container (OS)
  - Launch MAV/OS into low Mars orbit (~320 km orbit, ~20 deg inclination)
- Flight system
  - Pallet Lander deployed by MSL/M2020-heritage Skycrane or Propulsive Platform Lander
  - Solar powered (~16 m2 active area)

Artist's Concept

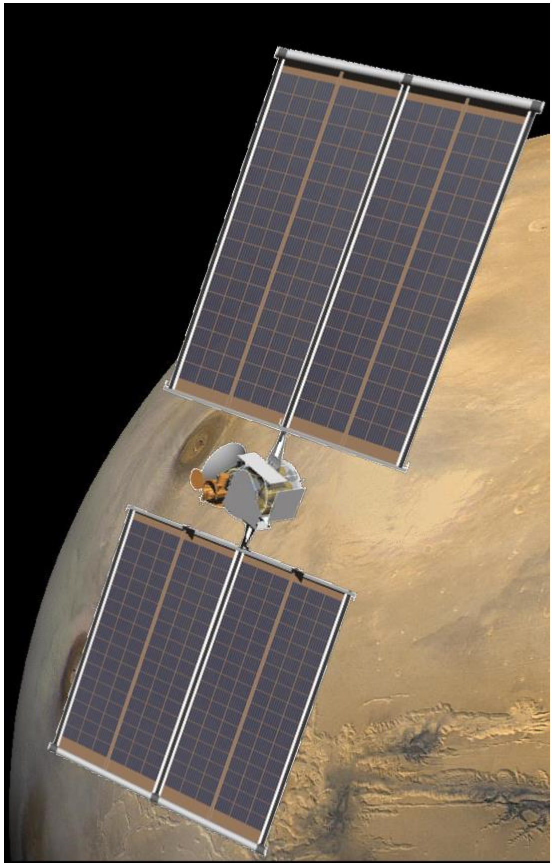


Pre-decisional information, for planning and discussion only

Notional Earth Return Orbiter

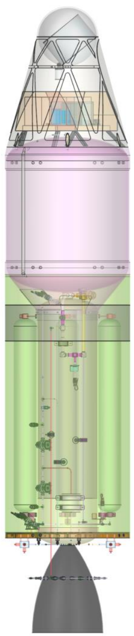
- Key functions
  - Communication telemetry and tracking during MAV launch
  - Rendezvous & Capture of on-orbit OS
  - Containment and Earth Planetary Protection
  - Return to Earth
- Payload
  - Capture/Containment and Return System (CCRS)
- Flight System
  - Currently assessing Chemical and Electric Propulsion options for this high-ΔV mission
  - Staging (jettison of orbiter elements prior to Earth return) likely required
- Status: ESA has initiated Phase A/B1 contracts with Airbus and TAS-I to develop ERO mission concepts

Artist's Concept



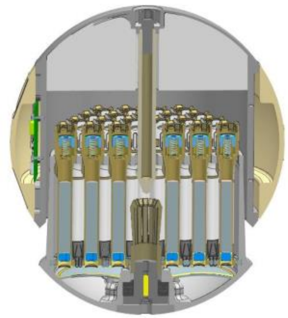
Key MSR Technology and Advanced Engineering Needs

Sample Retrieval Lander*



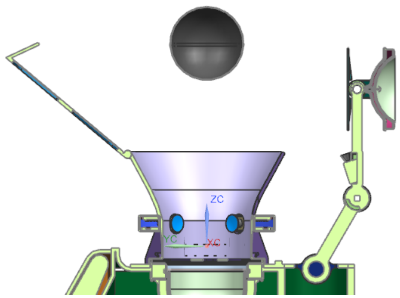
Mars Ascent Vehicle

Sample Fetch Rover

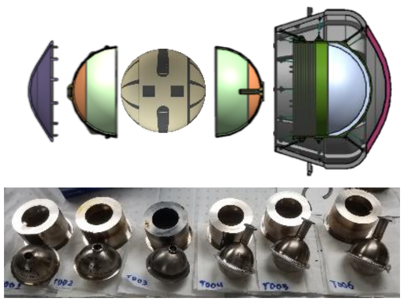


Orbiting Sample (OS) Container

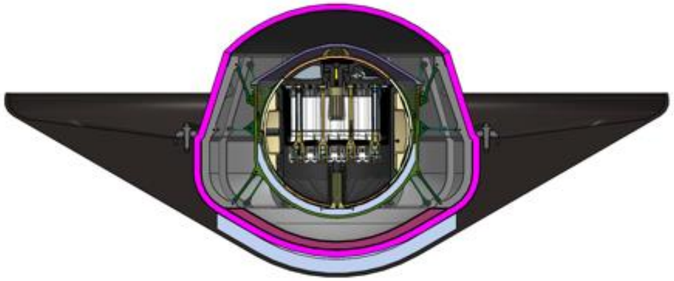
Earth Return Orbiter*



Rendezvous and Capture



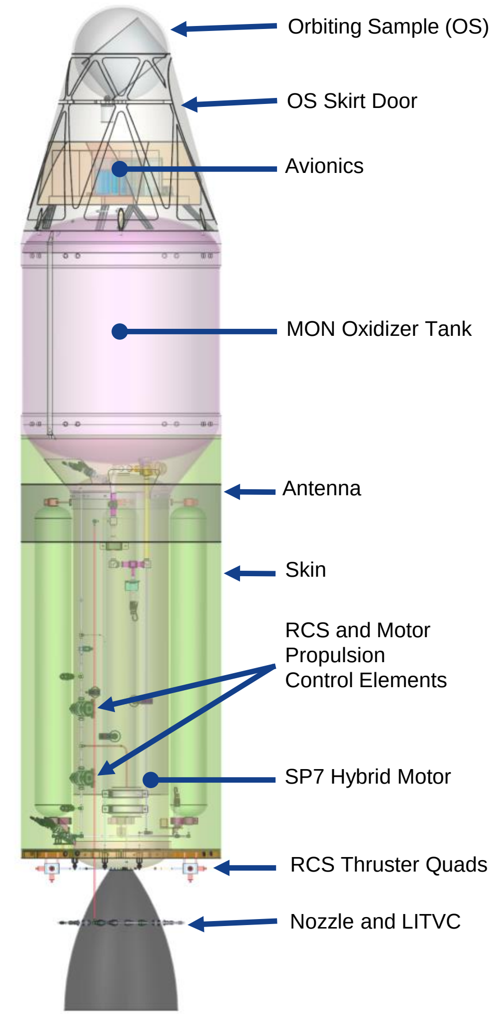
Containment Assurance



Earth Entry Vehicle

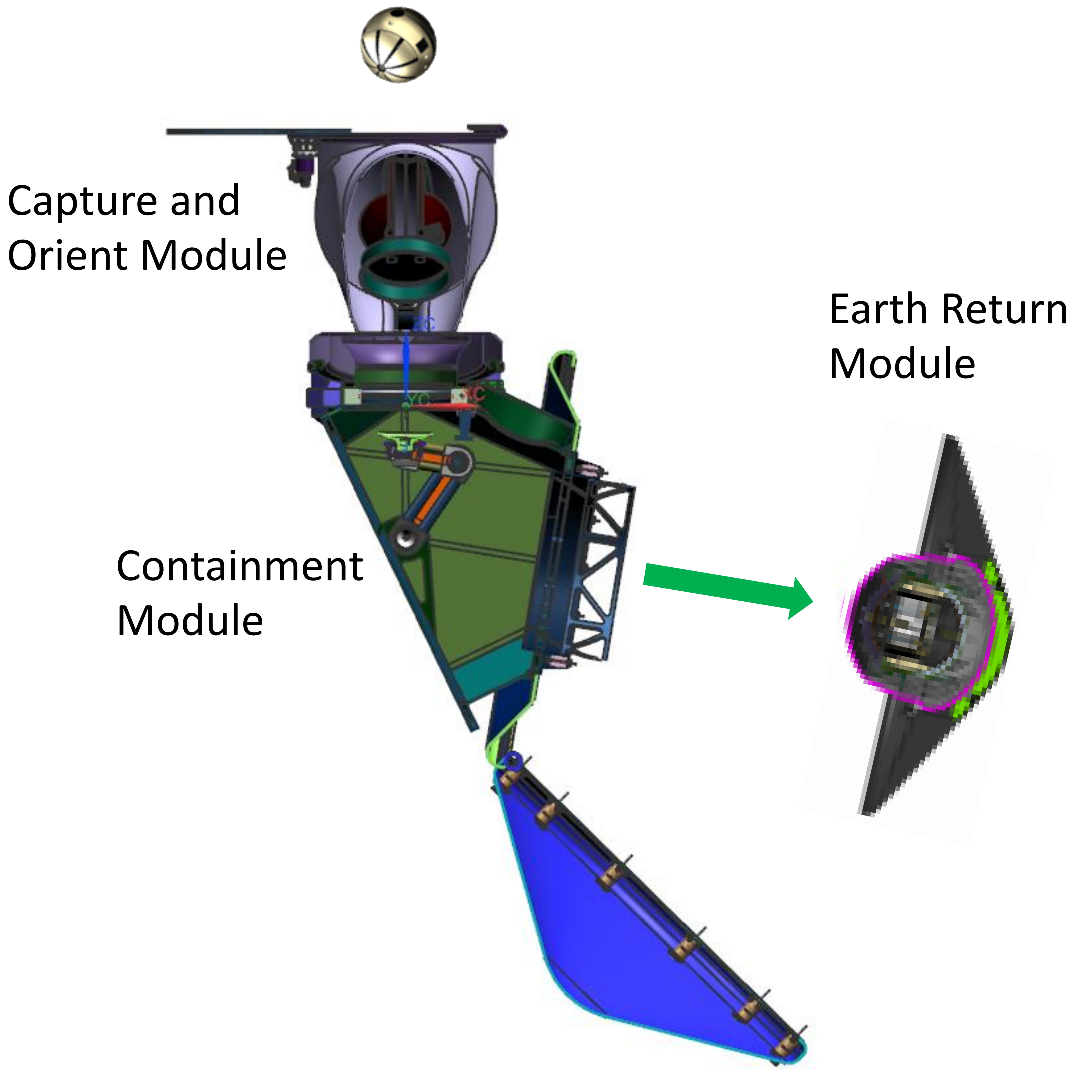
MAV Reference Design

- Hybrid propulsion option selected based on MAV trade study (JPL/MSFC/LaRC)
  - Single-Stage-To-Orbit Design
    - Target Orbit 320 km @ 20 deg Inclination
    - 12 kg OS Capability
    - Length: 2.4 m x Diameter: 0.57 m
  - GLOM Range: 290-305 kg (w/ 50% margin)
    - Varies with launch uncertainties
  - Mass Fractions
    - Propulsion Dry Mass : 10%
    - Non-propulsion Dry Mass : 12%
    - Oxidizer Mass: 63%
    - Fuel Core Mass: 14%
    - Helium Mass: <1%



Pre-decisional information, for planning and discussion only

Capture/Containment and Return System Concept



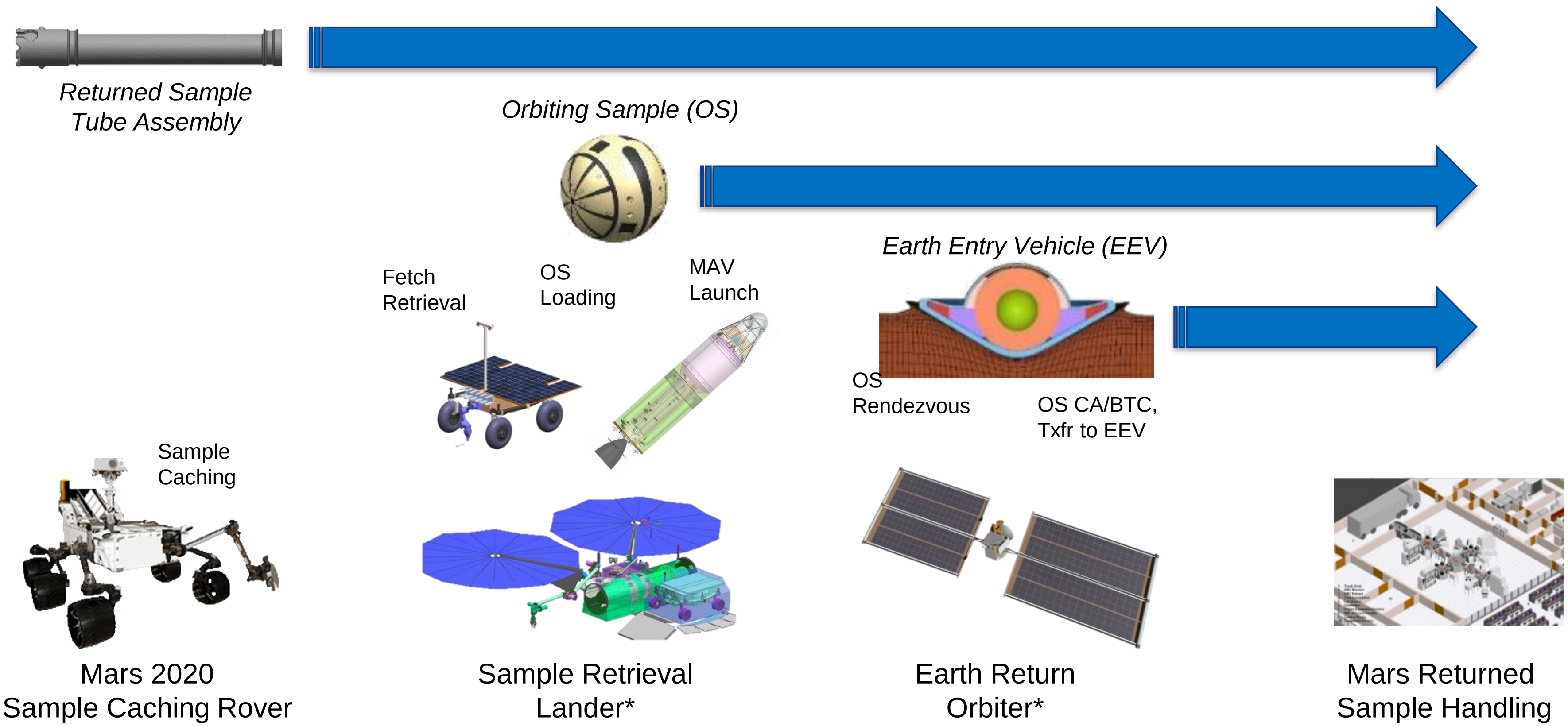
Pre-decisional information, for planning and discussion only

Summary

- The return to Earth of a scientifically selected set of diverse Martian samples is the next logical step in advancing our understanding of the Red Planet
- The most recent Planetary Decadal Survey has endorsed an MSR campaign architecture encompassing three missions:
  - Caching Rover [Mars 2020]
  - Sample Retrieval Lander
  - Earth Return Orbiter
- Mars 2020 is in development and provides the caching rover functionality
- NASA and ESA are now studying the potential SRL and ERO follow-on missions
- Key technology developments for the follow-on missions are underway
- Joint NASA/ESA study results will be available by end of CY 2019

Backup

Key MSR Cross-Element Interfaces



*Concepts

Key Campaign-level Technical Trades

M2020 Sample Caching Strategy
- Depot(s)
- Add’l M2020 Extended Mission Caching?
- M2020 Sample Tube Delivery?

SRL/ERO Joint Mission Timelines
- SRL/ERO Launch Dates
    - ERO chem vs. SEP propulsion
- SRL Surface Mission Timeline
- ERO Orbital RDV timeline
- ERO Relay Support to SRL?
- Earth return date

MAV
- Targeted Orbit (Altitude, Inclination)
- Delivered Orbit Accuracy

OS
- Mass/Volume
- RF Beacon?
- Atmospheric Samples?

Containment Assurance
- BTC on surface and/or in orbit
- CA method(s)

Earth Return Strategy
- Direct Earth Return
- Cis-Lunar Delivery w/ Crewed Return